Volcanic Eruptions and Effects on our Climate

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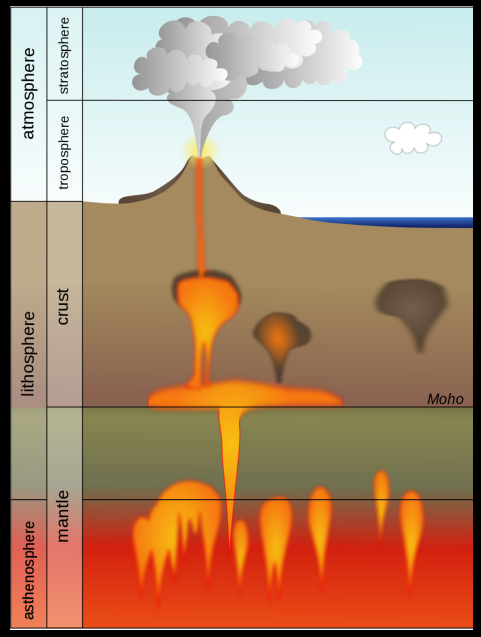
Volcano ‘Basics’

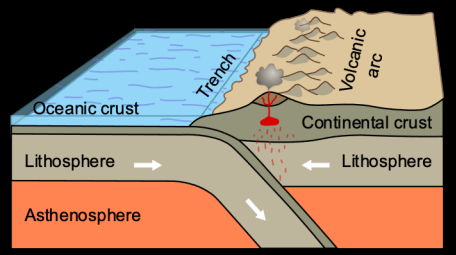
Volcanoes are an integral part of the Earth system and are formed by intrusions of magma that ‘bubble up’ from Earth’s interior (e.g., lava lamp).

They can form above thin areas of the Earth’s crust/ lithosphere known as ‘hot spots or mantle plumes’ such as the Hawaiian Islands or Yellowstone National Park.

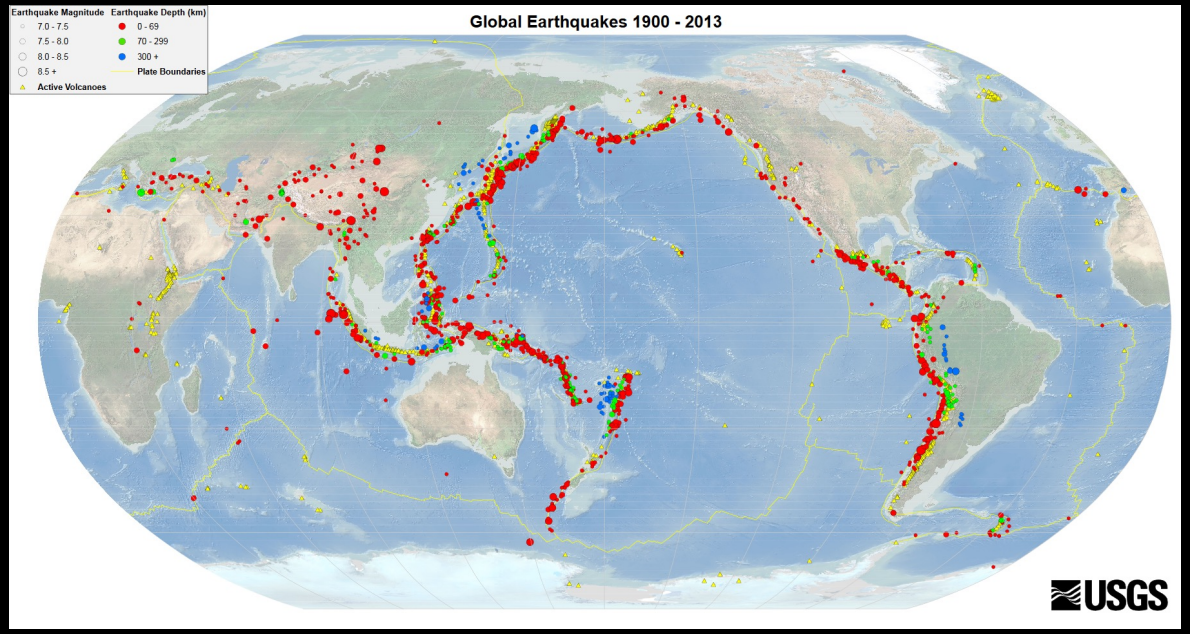
More commonly they form along ‘subduction zones’ where the thinner oceanic tectonic plates slide below the thicker continental plates.

Many of the most active (and violent) volcanos lie along subduction zones known as the Pacific ‘Ring of Fire’





Anatomy of a volcano and subduction zones (USGS)



www.usgs.gov/media/images/

Types of Eruptions

Lava contains dissolved O_2, Si, S, Na, Ca, K, steam, and many metals and eruptive forces depend upon the mixture of these components.

Eruptions are influenced by the chemistry of magma

1. Lava with lower viscosity (low SiO_2)– shield volcanos with lava flows (Ex: Mauna Loa, Kilauea, Galapagos Islands, Iceland)
2. Lava with higher viscosity – composite volcanos with pyroclastic eruptions (Ex: Vesuvius, Mt Fuji, Mt Kilimanjaro)

About 1500 volcanoes are active worldwide (~150 in USA) and only about 500 erupted in past 100 years

Mauna Loa is the world's largest active volcano – rising move than 2.5 miles above sea level and 5.5 miles above its base in the Pacific Ocean

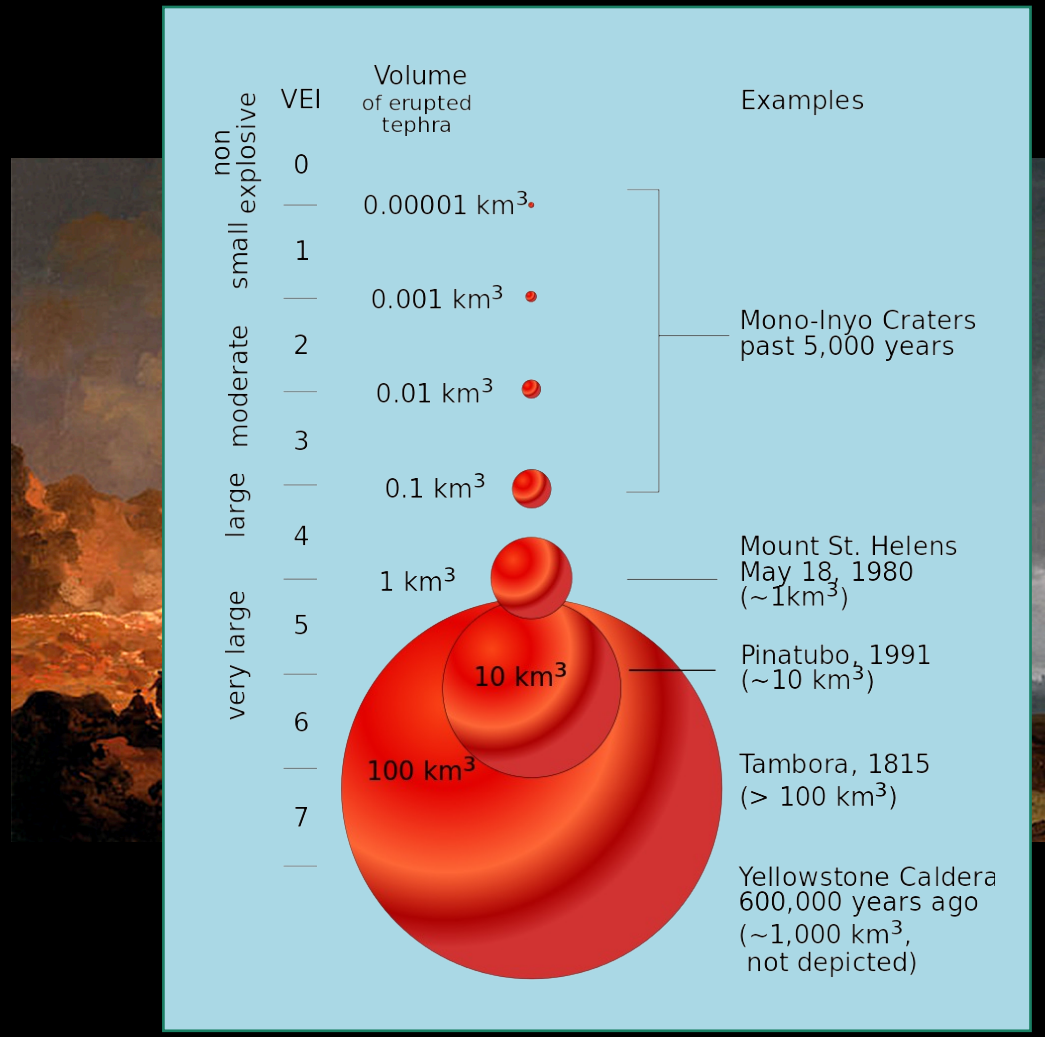
Kilauea Volcano and lava flow, 2018, (USGS; www.usgs.gov/media/images/k-lauea-volcano-fissure-8-lava-channel-4

Redoubt eruption, 2009 (USGS; www.usgs.gov/media/images/redoubt-volcano-minor-ash-eruption-photograph-taken-during-o)

Volcanic Explosivity Index

(VEI 0-8)

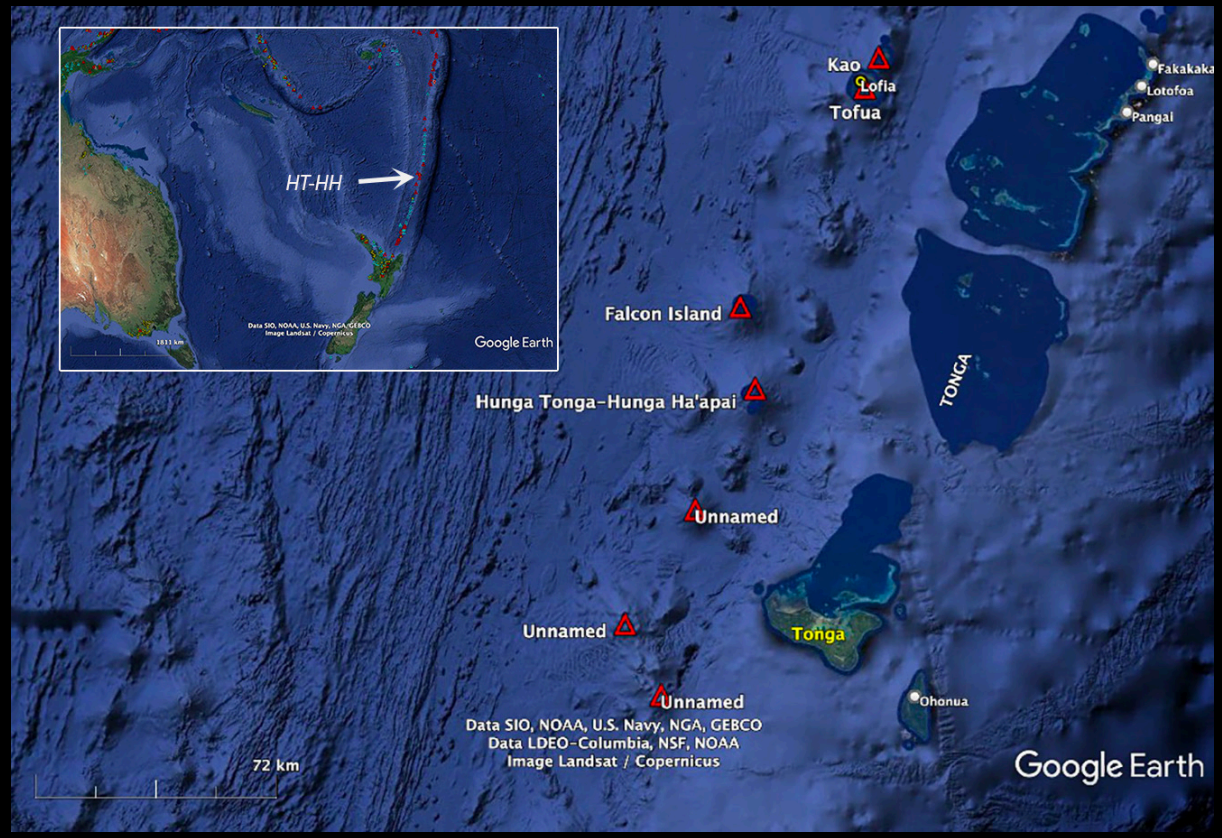
Name/Date	Description	Injection Impact to Stratosphere	VEI
Hawaiian (continuous)	Effusive	Negligible	0
Kilauea (2018)	Catastrophic	Negligible	3
Eyjafjallajoikul (2011)	Cataclysmic	Minor	4
Mt Vesuvius (79); St Helens (1980)	Paroxysmic	Significant	5
Krakatoa (1883); Pinatubo (1991)	Colossal	Substantial	6
Tambora (1815); Samalas (1257)	Super-colossal	Very Substantial	7
Yellowstone (630,000 BCE)	Mega-colossal	Vast	8



http://volcanoes.usgs.gov/Products/Pglossary/vei.html

Hunga Tonga-Hunga Ha’apai Eruption
(January 15, 2022)

- Violent, but short-lived eruption VEI 6-7
- Initial Plume rose to 58 km (36 miles)!
- Most explosive since Pinatubo (1991)
- Minor impact to stratosphere
- Boom heard in Alaska 7 hours after eruption
- Sound wave traveled twice around the Earth



Submarine eruption on
15-Jan-2022 at 4:15 UTC

Estimated 0.05 Tg of SO_2 emitted,
removed middle third of island [1]

Latest estimates of eruption duration only 10 minutes with 0.5 km^3 of rock ejected [2]

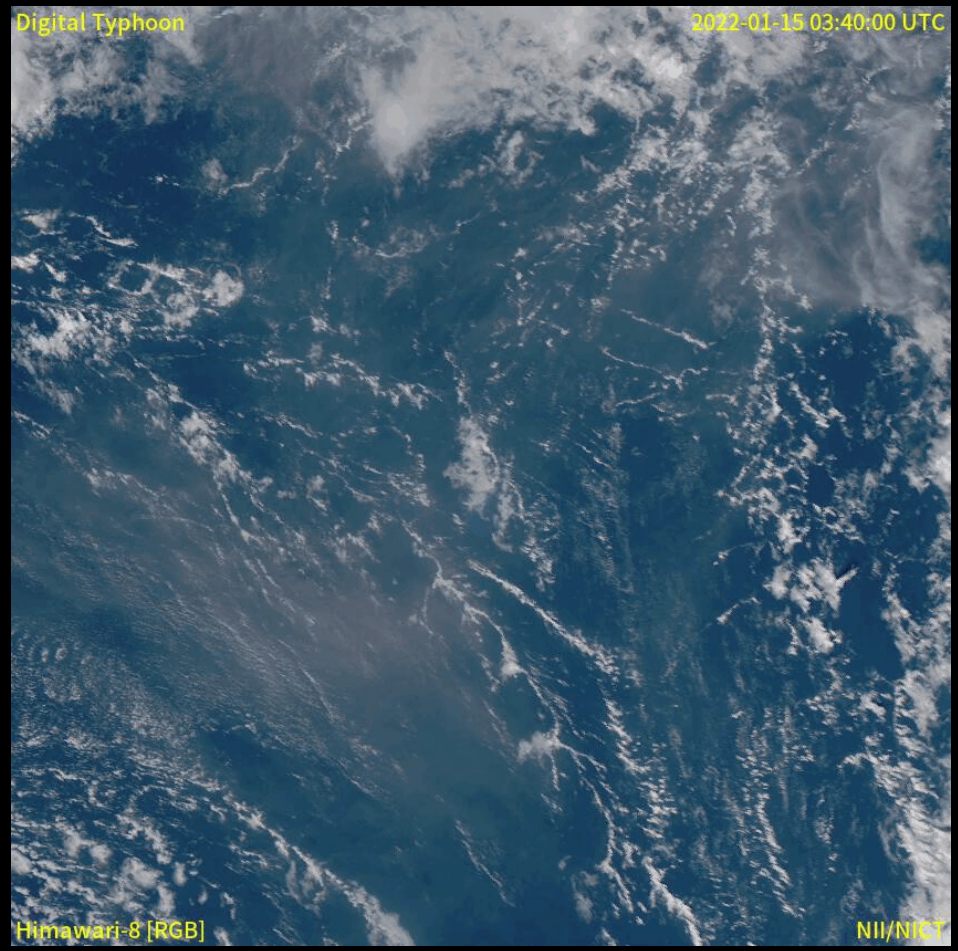
[1] Global Volcanism Program, 2022. Report on Hunga Tonga-Hunga Ha'apai (Tonga). In: Sennert, S K (ed.), Weekly Volcanic Activity Report, 12 January-18 January 2022. Smithsonian Institution and US Geological Survey.

[2] GeologyHub: https://www.youtube.com/watch?v=ce3SmA_UphA

IMAGE BY: TONGA GEOLOGICAL SERVICES
https://www.bbc.com/news/science-environment-60088413

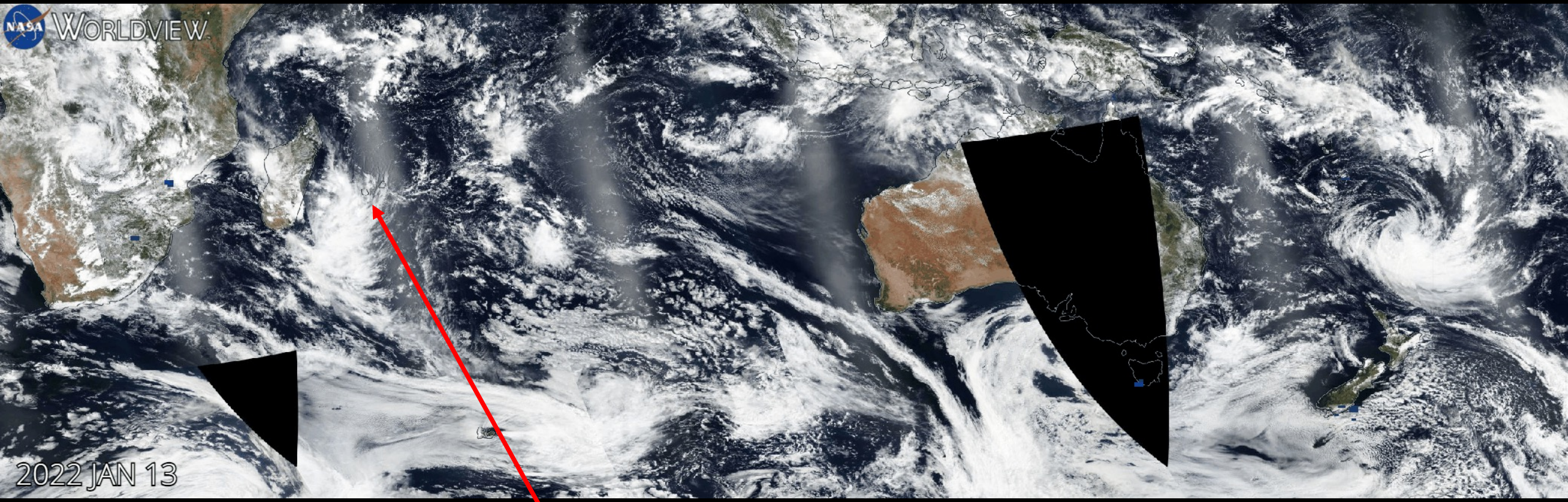
Hunga Tonga-Hunga Ha’apai Eruption
(January 15, 2022)

- Violent, but short-lived eruption VEI 6
- Initial Plume rose to 58 km (36 miles)!
- Most explosive since Pinatubo (1991)
- Equivalent to 4-18 megatons of TNT
- Minor impact to stratosphere
- Boom heard in Alaska 7 hours after eruption
- Sound wave traveled twice around the Earth




https://eol.jsc.nasa.gov/SearchPhotos/photo.pl?mission=ISS066&roll=E&frame=117996

Suomi NPP SO_2 observations
January 13 – 21



Sulfur Dioxide (Upper Troposphere and Stratosphere)
Suomi NPP / OMPS

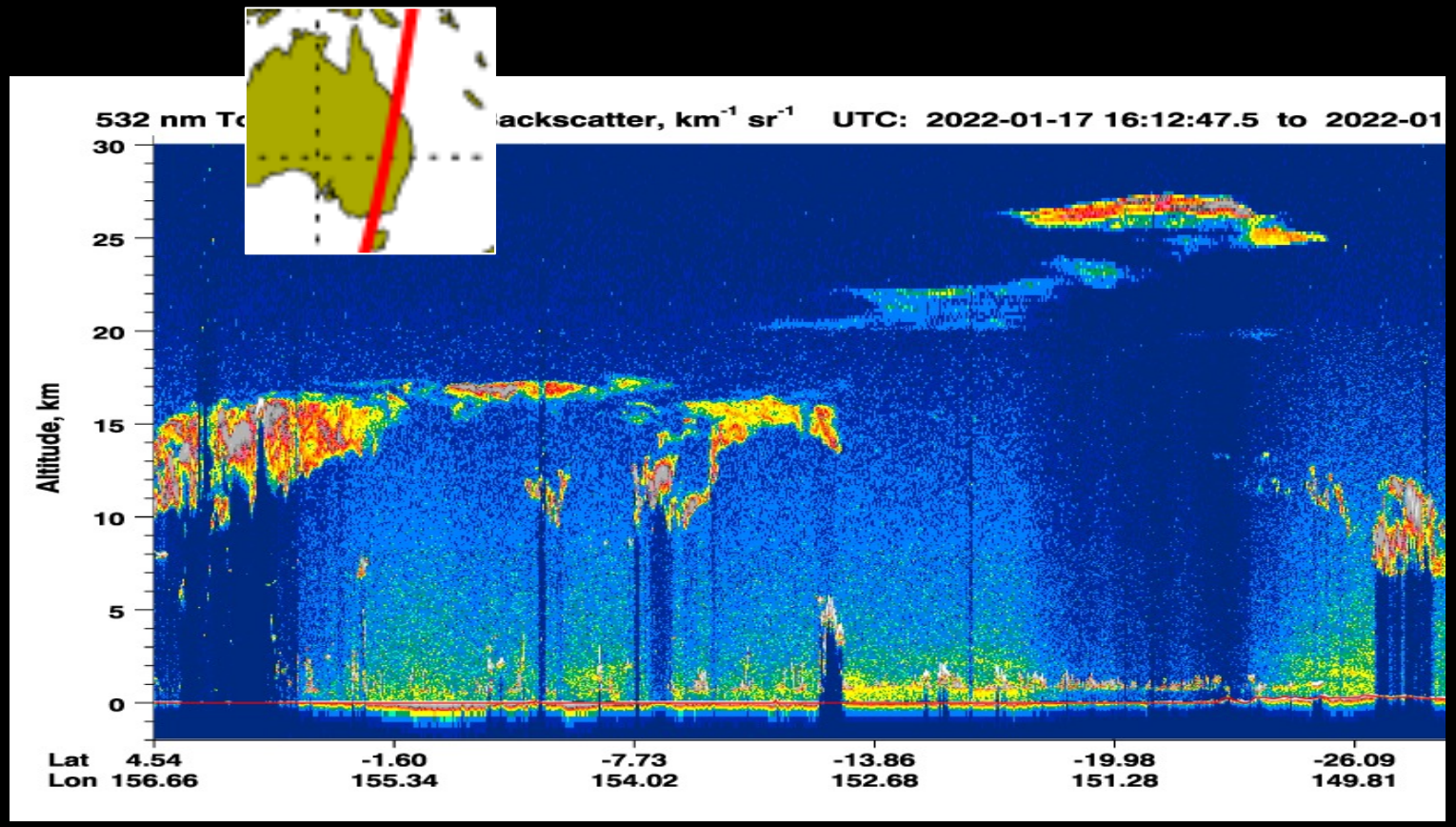
< 0.5 DU ≥ 32.0 DU

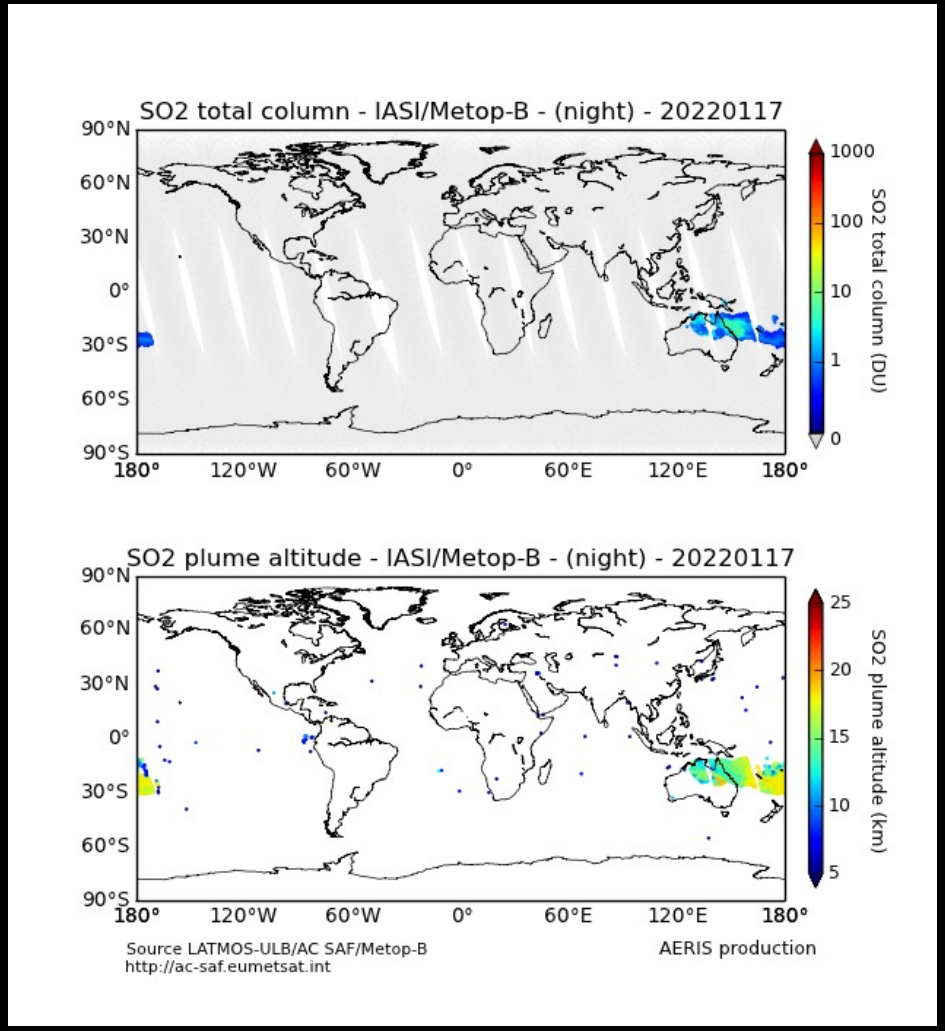
GEOS-5 simulations by Hyun Deok Choi predict plume over Reunion Island on 19-January. *(shared by Jean-Paul Vernier on ssircvolcano listserve, 22-Jan)*

CALIPSO

- CALIPSO is an important earth science satellite that measures the vertical distribution of clouds and particles/aerosols in the atmosphere
- The mission was launched in 2006 and has helped transformed our understanding on how clouds and aerosols influence climate, weather and air quality.
- CALIPSO is a partnership between NASA and the French Space Agency, CNES
- The CALIPSO Lidar is the primary instrument on the payload

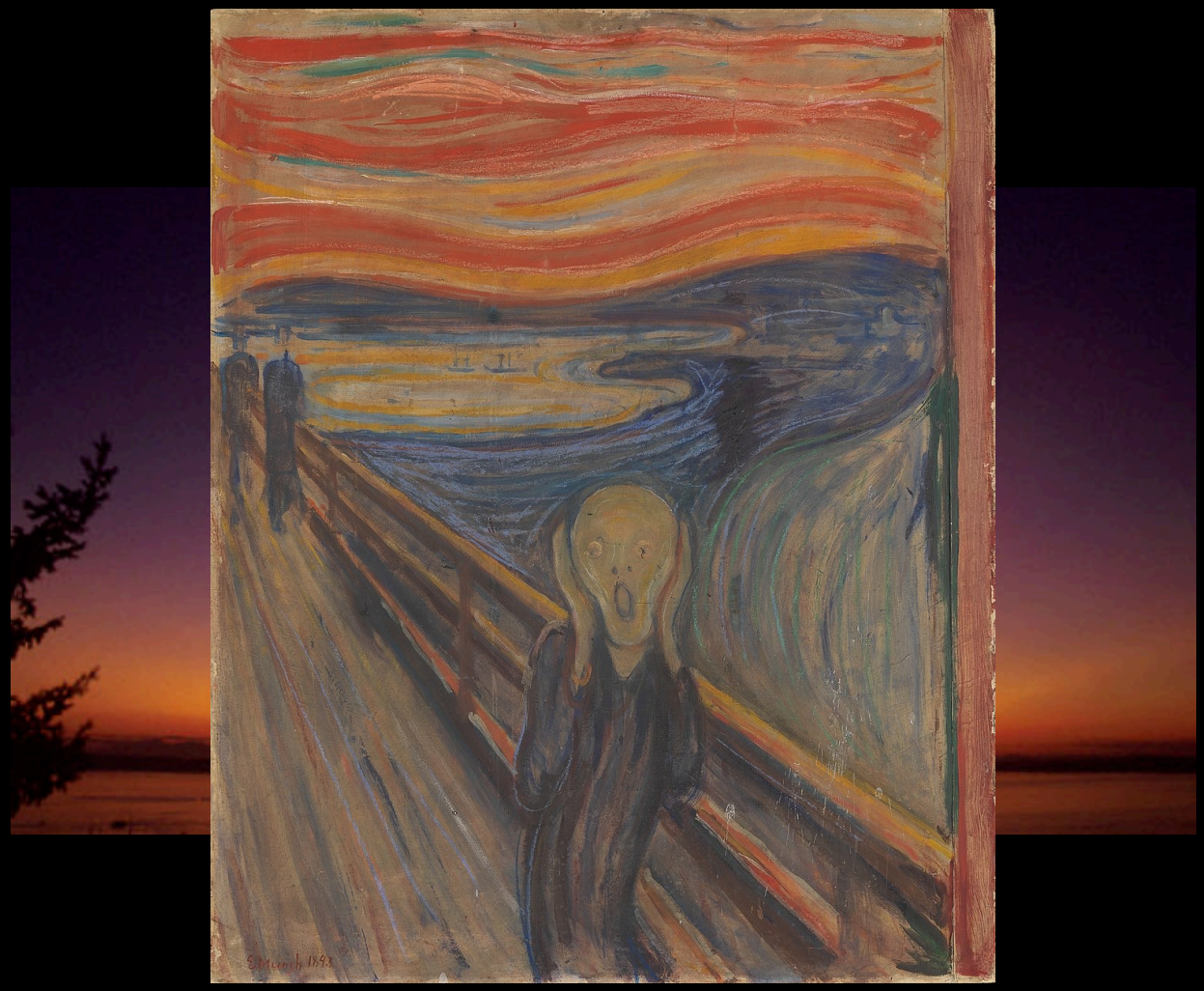
CALIPSO provides an ability to track the movement of volcanic plumes





Purple Skies After Large Eruptions

- Soon after an eruption, skies at twilight display vivid orange, red, and purple hues
- These skies can last for a couple of years
- Their occurrence is caused by the presence of tiny droplets (dia 1 μm) of sulphuric-acid that are formed from a volcanic SO_2 plume
  - Blue light scatter more easily than other colors and we can see blue skies away from the sun
  - Red light at sunset, more light passes through the atmosphere and more blue/violet light is lost leaving mostly red
  - Volcanic skies are a combination of light scatter in the lower atmosphere (red) and light scatter by small aerosols in stratosphere (blue)



The ‘Scream’ by Edvard Munch in 1893 has a volcanic sky thought to be from Krakatoa (1883).

An Early American Scientist

- Laki volcanic eruption in Iceland spewed sulfuric clouds into Europe – reported to have caused 8,000 deaths in Britain
- Also coincided in one of the coldest in many years i western Europe.
- Benjamin Franklin (US ambassador to France) first speculated on impact of eruption on climate ('weather')
- Meteorological Imaginations and Conjectures, [Ma 1784] (Franklin papers, https://founders.archives.gov/documents/Franklin/ 1-42-02-0184

Portrait of Benjamin Franklin (1706-1790) by Joseph Duplessis, 1778. (Credit: via The Metropolitan Museum of Art/Wikimedia Commons)

Climatic Effects

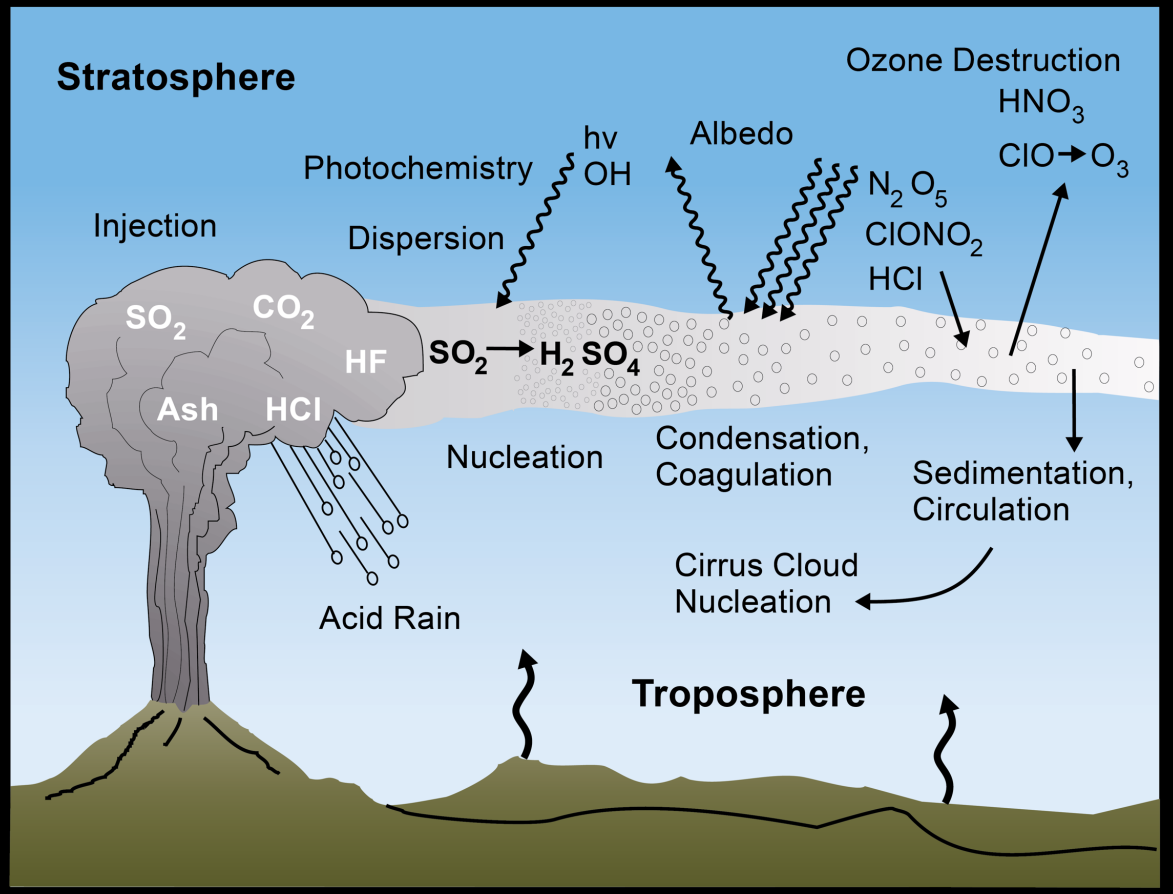
Large concentrations of volcanic aerosols reduce incoming sunlight and act to cool the Earth's surface (aka, Franklin, 1784)

- Pinatubo inject 20 megatons of SO_2 and, global surface temperatures decreased by ~ 1° F (1991-93)
- Laki eruption estimated to have emitted 120 megatons of SO2
- Europe experienced year without a summer after Tambora (1815)

Ozone depletion also can occur because aerosols enable surface chemistry to create compounds that destroy ozone

- Discovered by satellites and aircraft observations

Eruptions have not been observed to be a significant source of atmospheric carbon dioxide



https://www.usgs.gov/programs/VHP/volcanoes-can-affect-climate

Sobering Impacts

- Volcanos are believed to have played a major role with building the composition of Earth's early atmosphere
- Persistent and prolonged volcanic activity (million of years) caused by plate tectonics is further hypothesized to play a major role 3 of the 5 major extinction events
  - Ordovician-Silurian event (450-440 Ma) killed off 85% of all species
  - Permian-Triassic event (252 Ma) killed off 90 % of all species (Siberian volcanic traps)
  - Triassic-Jurassic event (201 Ma) 30% of life disappeared
- Bronze age collapse (1200-1150 BCE) thought to be initiated by 3 Icelandic volcanic eruptions – although evidence is inconclusive

The Age of Reptiles, a mural by Rudolph F. Zallinger.

Closing Thoughts

- We live in a rich and complex world that is ever changing.
- Volcanic eruptions are a regular part of the Earth System and can have an impact on our environment and climate.
- Large eruptions are rare – but when they occur they can have a profound impact to our world.
- Thank you for your interest.